II.

The Apparent Position of the Zodiacal Light.

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In all the explanations of the zodiacal light which have at present any claim to serious consideration, it is assumed that the light is due to finely divided matter of some kind, illuminated either by direct sunlight or by the result of electrical or chemical action. This matter may be only a portion of the atmosphere, or of some cosmical mass more or less homogeneous. But in this case the illumination is presumed to be confined within certain limits. The object, therefore, which observers of the zodiacal light have ordinarily proposed to themselves has been the discovery of the position and extent of the matter thus illuminated. Its apparent position in the sky was accordingly first to be determined at particular times, and large numbers of sketches, representing its visible limits, have been made for this purpose, especially within the last fifty years.

In a previous communication[1] I have attempted to derive, from the published work of the chief observers of the zodiacal light, some conclusions likely to be of service in planning future observations, rather than in determining the apparent position of the zodiacal light from those already made. The prominent result to be obtained from the comparison of sketches of the zodiacal light had always been an uncertainty whether the outlines depicted by the observers afforded any distinct information with regard to the real object to be observed. As is remarked by Schmidt,[2] all the observations accumulated in the twelve years preceding 1868 seemed to add nothing to our knowledge with regard to the constitution and position of the zodiacal light. On this account, Schmidt recommends closer attention to the faint light sometimes seen in opposition to the Sun, and apparently due to causes of the same kind with those by which the zodiacal light itself is produced.

[1] Proc. Am. Acad. XIX. 146.

[2] Astronomische Nachrichten, LXXII. 342.

The first definite discovery tending to account for the perplexing discordances above mentioned, in the results of observation, was made by Jones,[1] who found that the apparent position of the light varied, in general, with the inclination of the ecliptic to the horizon. In the article already mentioned, I stated, as the apparent result of the data there collected, that this law is confirmed by the experience of other observers as well as by that of Jones, and that it should be referred to the effect of atmospheric absorption, as has been suggested by Geelmuyden. A further inference is that the method of observation by drawing outlines, as heretofore practised, is insufficient, and that it must be replaced by photometric observation of some sort.

It may be practicable, however, to obtain from the older observations some suggestion with regard to the apparent position of the zodiacal light, after correcting them roughly for the presumed effect of atmospheric absorption. Any suggestion thus attainable will lend additional interest to the work of future observers, although it can have no great importance of its own. In undertaking the inquiry, we shall be obliged to limit ourselves to the comparison of observations made by the same observer, since we already know that different observers form very different conceptions with regard to the outlines of the zodiacal light. It will also be desirable to compare observations made at the same elongation from the Sun, but at points differing considerably in altitude while they differ little in longitude. We likewise require observations made in as many different parts of the zodiac as possible. No published observations except those of Jones fulfil these conditions even approximately, and the inquiry here undertaken is therefore limited to the work of that observer.

The selection of observations for discussion was determined by the joint consideration of the time required by the reductions and the probable interest of the results to be derived from them. Upon the whole, it seemed best to employ all observations of what was called by Jones the "Stronger Light," made either in the evening or in the morning at the elongation 60°, and to omit the remainder. The limits of the light at this elongation are given for the evening observations in my former communication, Table X.[2] In collecting and reducing them for the present purpose, the following corrections were noticed to be required by that table. Under the date of Nov. 4, 1853, column "Elongation of Vertex," for the "Stronger Light," the figures 79, 82, 94, should be 80, 85, 96; for the "Diffuse Light," 106, 110, 114, 120 should be 109, 113, 117, 124; the data for

[1] Observations on the Zodiacal Light, Introduction, p. xvi.

[2] Proc. Am. Acad. XIX. 183–191.

the latitude of the boundaries of the "Stronger Light" at the elongation 60° should be omitted, as not determinable from the sketch. Under the date of July 15, 1854, the last result for the latitude of the boundaries of the "Stronger Light" at 60° should also be omitted. Under the date of Aug. 17, 1854, column "*t*," the last result, 18, should be 13.

The required data for the morning observations of Jones at the elongation 60° were obtained from his work by the method previously employed;[1] but the longitude of the sun was referred to a date one day earlier than that given by Jones, who employs civil time, so that the same longitude might be retained for all observations belonging to the same night, whether made early or late. This precaution, however, is of no practical importance, and might have been neglected without noticeably affecting the results, since a single degree is a relatively small quantity in the data here collected, and given below in Table I., the headings of which have the same meaning as those corresponding to them in Table X., already mentioned. An additional column in the present table gives the excess of absorption at the southern over that at the northern boundary, computed in terms of stellar magnitude by means of an auxiliary chart and the tables given in my former communication. As previously, negative quantities are indicated by Italic figures.

TABLE I.

Morning Observations by Jones: Stronger Light: Elongation 60°.

No. of Chart.	Date. 1853.	Long. of Sun.	Lat. of Obs.	*t*.	Lat. of Bound.		Diff. Absorption.	No. of Chart.	Date. 1853.	Long. of Sun.	Lat. of Obs.	*t*.	Lat. of Bound.		Diff. Absorption.
					N.	S.							N.	S.	
		°	°	°	°	°				°	°	°	°	°	
13	June 15	83	26.2	38	4	6	0.29	53	Sept. 12	168	23.0	141	9	10	0.05
30	July 9	106	35.2	62	7	6	0.22					147	5	5	0.01
33	July 11	108	35.2	57	13	9	0.51	55	Sept. 14	171	23.0	121	8	6	0.13
35	July 13	110	35.2	59	10	7	0.40					128	8	6	0.05
37	July 15	112	35.4	53	10	9	0.87					143	6	9	0.02
				68	5	3	0.09	56	Sept. 15	172	23.0	133	4	6	0.02
38	July 16	113	35.4	54	10	5	0.45					144	6	6	0.02
39	July 18	115	33.7	56	9	8	0.73					149	3	2	0.00
				71	11	6	0.21	60	Sept. 30	186	22.4	144	7	5	0.03
40	July 19	116	32.1	72	7	0	0.07	62	Oct. 1	187	22.4	144	6	4	0.03
42	Aug. 5	132	21.5	103	5	10	0.06					152	6	5	0.02
43	Aug. 16	143	23.0	114	6	9	0.05					159	5	2	0.01
49	Sept. 2	158	23.0	111	8	8	0.13	64	Oct. 3	189	22.4	146	7	5	0.00
				124	10	8	0.04					161	6	5	0.00
50	Sept. 3	159	23.0	117	10	7	0.07	66	Oct. 4	190	22.4	147	7	5	0.00
				125	6	7	0.04					162	5	7	0.01

[1] Proc. Am. Acad. XIX. 171.

No. of Chart.	Date. 1853–1854.	Long. of Sun.	Lat. of Obs.	t.	Lat. of Bound. N.	Lat. of Bound. S.	Diff. Absorption.	No. of Chart.	Date. 1854.	Long. of Sun.	Lat. of Obs.	t.	Lat. of Bound. N.	Lat. of Bound. S.	Diff. Absorption.
		°	°	°	°	°				°	°	°	°	°	
67	Oct. 8	194	22.2	151	9	5	0.00	177	July 7	104	28.9	58	12	11	0.42
				166	5	8	0.01					64	12	9	0.25
77	Oct. 31	217	22.4	174	5	5	0.00	178	July 8	105	29.2	61	13	9	0.29
79	Nov. 1	218	22.4	175	4	3	0.00					70	10	7	0.14
				190	5	1	0.00	187	July 24	121	25.6	66	12	9	0.48
81	Nov. 2	219	22.4	191	5	4	0.00					85	11	6	0.10
85	Nov. 8	225	22.4	182	11	6	0.00	189	July 25	122	25.6	65	12	6	0.45
				197	7	6	0.00					80	10	6	0.12
90	Dec. 29	276	22.3	240	7	7	0.07	191	July 26	123	24.4	79	12	9	0.22
				247	12	7	0.13	192	July 29	126	20.7	67	13	9	0.72
				262	6	7	0.05					82	13	9	0.20
92	Dec. 30	277	22.3	256	10	6	0.08					97	11	6	0.07
				268	10	7	0.06	193	July 31	127	19.5	83	12	10	0.20
94	Dec. 31	279	22.3	249	14	5	0.10					98	12	10	0.07
				264	13	8	0.08	194	Aug. 1	128	18.6	88	15	11	0.17
				269	14	8	0.08					99	13	10	0.06
97	Jan. 3	282	22.3	245	12	7	0.12	195	Aug. 4	131	17.8	98	14	9	0.07
				260	13	8	0.09	199	Aug. 21	148	14.5	108	11	10	0.04
99	Jan. 4	283	22.3	253	16	6	0.12	201	Aug. 22	149	14.8	120	11	11	0.01
				269	14	6	0.08	203	Aug. 23	150	16.0	121	10	9	0.00
				270	12	6	0.08	205	Aug. 24	151	18.6	122	10	10	0.03
100	Jan. 5	284	22.3	265	23	5	0.10					130	8	10	0.01
101	Jan. 6	285	22.3	255	30	5	0.17	207	Aug. 26	153	21.0	124	8	10	0.03
102	Jan. 10	289	22.3	259	12	4	0.13	208	Aug. 28	155	22.3	104	11	14	0.28
				274	12	4	0.08					118	9	12	0.09
				275	10	4	0.06	209	Aug. 29	156	22.3	97	14	12	1.28
				276	11	4	0.07					127	8	10	0.03
103	Jan. 11	290	22.3	260	11	4	0.13	210	Aug. 31	157	22.3	110	10	7	0.13
				270	12	4	0.10	211	Sept. 4	160	22.3	126	9	9	0.03
				275	12	4	0.07					140	7	9	0.01
				280	12	4	0.07	216	Sept. 19	175	29.8	122	8	8	0.26
110	Jan. 30	309	26.2	279	21	4	0.31	217	Sept. 20	176	32.1	149	7	7	0.03
				294	13	0	0.08	219	Sept. 21	177	33.9	120	9	7	0.38
112	Jan. 31	310	26.2	284	13	4	0.26	221	Sept. 27	183	34.7	156	7	7	0.04
				295	23	1	0.17	222	Sept. 28	184	34.7	157	8	8	0.05
114	Feb. 1	311	26.5	295	23	1	0.18	223	Sept. 30	186	34.7	148	7	11	0.11
115	Feb. 2	312	26.8	289	24	4	0.29					163	8	8	0.03
116	Feb. 4	314	26.6	298	22	1	0.18	232	Oct. 20	206	28.1	182	11	4	0.01
130	Mar. 27	5	35.4	339	15	*6*	0.20					189	8	4	0.01
				342	15	*5*	0.17	233	Oct. 21	207	26.0	179	12	4	0.00
132	Mar. 28	6	35.4	335	19	*8*	0.28	236	Oct. 25	211	21.3	164	14	3	0.00
				343	19	*5*	0.25					183	12	3	*0.02*
134	Mar. 29	7	35.4	336	18	*8*	0.29	237	Oct. 30	216	21.3	184	12	2	0.00
137	Apr. 1	10	35.4	339	18	*8*	0.28	238	Nov. 1	218	21.3	179	13	3	*0.03*
				347	18	*5*	0.23					194	10	5	*0.01*
145	Apr. 26	35	34.7	359	17	1	0.54	241	Nov. 20	237	36.3	209	14	3	0.09
147	Apr. 27	36	34.7	5	17	2	0.43					224	11	3	0.05
172	June 30	97	28.4	46	16	11	0.72	243	Nov. 21	238	37.3	214	13	4	0.08
				58	11	8	0.27					229	9	4	0.06
173	July 1	98	27.6	39	22	12	2.78	245	Nov. 25	242	38.0	217	10	2	0.06
				54	15	8	0.33					232	8	2	0.04
				62	10	5	0.19	246	Nov. 27	244	38.0	219	11	3	0.09
175	July 5	102	29.8	47	18	12	1.21					234	9	3	0.06
				62	13	9	0.44								

No. of Chart.	Date. 1854–1855.	Long. of Sun.	Lat. of Obs.	t.	Lat. of Bound.		Diff. Absorption.	No. of Chart.	Date. 1855.	Long. of Sun.	Lat. of Obs.	t.	Lat. of Bound.		Diff. Absorption.
					N.	S.							N.	S.	
		°	°	°	°	°				°	°	°	°	°	
247	Nov. 28	245	38.0	201	16	4	0.30	304	Mar. 17	355	*22.9*	313	8	8	*0.02*
				231	12	4	0.07					324	7	5	0.00
259	Dec. 19	266	31.0	229	14	10	0.31					332	4	4	0.00
				252	11	6	0.08	306	Mar. 20	358	*22.9*	331	7	6	*0.01*
263	Dec. 21	268	26.0	239	14	7	0.11					334	5	6	0.00
264	Dec. 22	269	23.3	255	11	5	0.05	307	Mar. 21	359	*22.9*	313	7	8	*0.03*
266	Dec. 25	273	17.4	228	11	7	0.00					335	5	6	0.00
				250	9	4	0.03	309	Mar. 23	1	*22.9*	315	8	8	*0.07*
268	Dec. 26	274	16.0	251	10	5	0.02	309	Mar. 23	1	*22.9*	330	6	7	0.00
270	Dec. 29	277	11.6	232	12	9	0.00					337	5	5	0.00
				254	10	5	0.02	310	Mar. 24	2	*22.9*	316	8	9	*0.08*
271	Dec. 30	278	19.8	255	13	6	0.06					331	7	7	0.00
272	Jan. 1	280	7.4	257	12	7	0.00					339	5	6	0.00
282	Jan. 18	297	*3.7*	263	14	9	*0.07*	311	Mar. 26	4	*22.1*	323	7	8	0.00
				275	10	9	0.00	312	Mar. 28	6	*19.5*	335	7	8	0.00
284	Jan. 19	298	*6.0*	253	16	11	*0.23*					342	6	7	0.01
				276	13	11	*0.02*	313	Mar. 29	7	*17.4*	321	8	8	0.00
286	Jan. 22	301	*12.8*	264	14	9	*0.11*					336	7	7	0.01
				278	12	9	*0.03*					344	6	6	0.01
287	Jan. 23	302	*14.7*	250	16	11	*0.53*	318	Apr. 13	22	18.1	343	11	9	0.76
				279	14	11	*0.04*	320	Apr. 14	23	21.0	345	12	8	0.76
288	Jan. 30	309	*29.1*	264	16	10	*0.37*					356	10	4	0.22
				279	16	7	*0.14*	322	Apr. 16	25	25.5	358	11	9	0.47
297	Feb. 23	333	*52.5*	280	5	9	*0.23*	324	Apr. 17	26	28.0	344	13	6	1.96
298	Feb. 28	338	*40.8*	292	14	10	*0.40*					359	15	6	0.43
299	Mar. 1	339	*39.2*	293	8	11	*0.19*	325	Apr. 18	27	30.5	345	12	6	1.92
302	Mar. 16	354	*22.9*	312	8	6	*0.05*					0	14	6	0.47
				323	7	6	0.00	327	Apr. 19	28	33.2	346	13	5	1.56

The differences of absorption corresponding to the evening observations of the "Stronger Light" at the elongation 60° were likewise computed from the material collected in the previous communication above mentioned. The longitude of the point to which each observation relates was found from the longitude of the Sun. The latitude of the axis, that is, the mean of the two latitudes given for the boundaries of the light, was also computed for each observation.

The evening and the morning observations were then separately arranged in groups, each covering ten degrees of longitude. When the observations forming one of these groups had all been made under similar circumstances, and presented a general resemblance to each other, it was practicable to employ their mean results in the subsequent discussion. But in other cases, parts of adjacent groups were combined to form new groups; no group, however, was made to include more than thirty degrees of longitude. The mean results for all the groups are given in Table II. Those derived from the morning observations are placed by themselves after the others, as is shown in the first column. The

second column contains the numbers of the first and last charts employed in forming each group, which are given in order to assist in identifying the portions of previous tables here combined. When the observations of any group were not all made in the same season, the numbers given in the second column will differ

TABLE II.

Class.	Limiting Nos. of Charts.	Limiting Longitudes.	No. Obs.	Long.	Half Ext.	Diff. Abs.	Incl. Ecl.	Lat. Axis.	Remainders.			Corrected Latitudes.		
									Abs.	Incl.	Lat.	Abs.	Abs.	Incl.
		° °		°	°		°	°		°	°	°	°	°
Evening Observations.	106, 113	5, 11	11	7.6	8.1	0.04	85.5	0.8	*0.68*	54.2	*3.9*	0.3	0.3	0.4
	285, 293	0, 23	7	13.9	9.3	*0.64*	139.7	*3.1*	0.71	*62.1*	4.3	1.0	0.8	0.5
	117, 119	26, 29	9	27.9	7.9	0.07	77.6	1.2	*0.01*	0.2	*0.7*	0.4	0.4	0.3
	120, 124	31, 36	11	33.6	7.7	0.06	77.8	0.5	*0.25*	45.3	*3.0*	*0.2*	*0.3*	*0.4*
	300, 315	53, 79	15	61.9	6.5	*0.19*	123.1	*2.5*	0.35	*50.6*	4.4	*0.7*	*1.0*	*0.1*
	3, 136	57, 75	14	64.5	6.7	0.16	72.5	1.9	0.02	4.5	*0.5*	0.4	0.4	0.6
	138, 326	80, 88	21	84.5	10.2	0.18	77.0	1.4	*0.01*	*12.9*	1.3	*0.3*	0.0	0.5
	140, 149	90, 99	16	93.9	8.0	0.17	64.1	2.7	0.12	*23.0*	1.8	1.1	1.2	0.8
	152, 161	114, 128	15	118.6	7.6	0.29	41.1	4.5	0.43	0.1	1.4	2.1	2.2	0.9
	16, 171	150, 167	18	156.0	11.0	0.72	41.2	5.9	*0.23*	2.2	*0.4*	1.7	1.7	2.3
	179, 190	171, 182	21	176.6	8.0	0.49	43.4	5.5	*0.22*	6.7	*1.1*	2.1	2.3	2.1
	48, 212	200, 229	18	209.8	7.5	0.27	50.1	4.4	*0.02*	*10.6*	*1.3*	2.1	2.3	1.5
	213, 224	230, 258	10	236.0	4.8	0.25	39.5	3.1	*0.04*	16.9	*2.5*	1.0	1.0	*0.5*
	76, 242	270, 298	9	285.2	6.7	0.21	56.4	0.6	*0.01*	*0.5*	0.2	*1.3*	*1.3*	*1.9*
	244, 252	300, 319	10	315.1	5.8	0.20	55.9	0.8	*0.08*	10.0	0.5	*1.0*	*1.0*	*1.7*
	88, 262	320, 329	17	324.6	5.7	0.12	65.9	1.3	*0.08*	15.5	*0.8*	*0.1*	0.1	*0.5*
	89, 265	330, 338	13	336.6	8.4	0.04	81.4	0.5	*0.06*	14.0	*1.3*	0.0	0.0	*0.2*
	96, 276	342, 349	13	346.5	7.4	*0.02*	95.4	*0.8*	*0.05*	7.1	*0.7*	*0.3*	*0.4*	*0.4*
	104, 283	350, 358	24	353.7	7.9	*0.07*	102.5	*1.5*	0.11	*17.0*	2.3	*0.4*	*0.5*	*0.6*
Morning Observations.	13, 173	23, 38	6	35.1	10.6	0.76	49.7	2.1	*0.34*	*0.4*	*0.5*	*2.4*	*1.7*	*2.7*
	30, 178	42, 56	15	48.6	9.0	0.42	49.3	1.6	*0.21*	18.9	*0.2*	*1.5*	*1.3*	*3.3*
	42, 195	61, 72	14	65.7	10.2	0.21	68.2	1.4	*0.09*	13.6	*1.5*	*0.5*	*0.3*	*1.2*
	43, 211	83, 108	20	95.7	9.2	0.12	81.8	*0.1*	*0.06*	0.6	0.3	*1.3*	*1.0*	*1.1*
	55, 223	111, 129	19	120.1	6.4	0.06	82.4	0.2	*0.06*	7.5	1.9	*0.5*	*0.4*	*0.8*
	66, 238	130, 159	16	148.3	6.3	0.00	89.9	2.1	0.08	*15.5*	1.4	2.1	2.2	2.1
	85, 247	165, 185	12	178.5	7.3	0.08	74.4	3.5	*0.01*	3.3	*1.3*	2.6	2.7	1.5
	90, 271	206, 219	18	214.5	8.9	0.07	77.7	2.2	0.03	*6.2*	2.3	1.4	1.4	0.8
	97, 103	222, 230	15	226.5	9.6	0.10	71.5	4.5	*0.24*	30.1	*2.4*	3.4	3.5	2.3
	272, 288	220, 249	11	239.5	11.7	*0.14*	101.6	2.1	0.35	*43.3*	6.5	3.5	3.3	3.5
	110, 116	249, 254	7	250.7	11.0	0.21	58.3	8.6	*0.28*	42.9	*8.6*	6.7	6.7	4.8
	297, 307	273, 299	12	291.4	7.1	*0.07*	101.2	0.0	0.06	*10.6*	*0.2*	0.8	0.7	1.3
	309, 313	301, 307	12	303.8	6.9	*0.01*	90.6	*0.2*	0.25	*56.7*	12.2	*0.1*	*0.1*	*0.1*
	130, 137	305, 310	7	307.0	5.5	0.24	33.9	12.0	0.63	5.6	*8.2*	9.9	9.9	5.4
	145, 327	322, 336	11	327.1	9.4	0.87	39.5	3.8	*0.11*	10.2	*1.7*	*1.1*	*0.8*	*2.2*

considerably. The third column gives the extreme longitudes comprised in each group, and will also assist in identifying the original observations. The next six columns give the number of observations comprised in each group, the mean longitude to which they relate, and the mean results for four other quantities; first,

half the sum of the latitudes of the boundaries, here designated as half the extent of the light; second, the difference of absorption at the boundaries, expressed as in Table I.; third, the zenith distance of the north pole of the ecliptic, here called the inclination of the ecliptic; and fourth, the latitude of the axis, as above defined. The next three columns, headed "Remainders," contain differences found from the three preceding columns, by subtracting the quantities given in each line from those in the next line below. The remainders in the last lines of the evening and morning observations are found by subtracting the quantities contained in them from those in the corresponding first lines. A system of corrections, which will be explained below, was derived from these remainders. The three final columns of Table II. contain corrected values for the latitude of the axis. The first two of these columns result from corrections determined by the difference of absorption; the same system of corrections is respectively applied in the two cases to the mean values in Table II., and to the separate observations from which these mean values were derived. There is no material difference in the result of these methods. The corrected latitudes in the last column are determined by the inclination of the ecliptic, instead of by the difference of absorption; the corrections were applied to the mean values in Table II. As in Table I., negative quantities are indicated by Italic figures.

We know already that the latitude of the axis varies to some extent in accordance with the difference of absorption at the boundaries of the light, as well as with the inclination of the ecliptic, and it is obvious that Table II. exhibits variations of this kind. We should presumably find similar relations between the latitude of the axis and the mean of the amounts of absorption at the boundaries, or their ratio; but there is little reason to suppose that any function of the absorption would be better adapted to the present purpose than the difference here employed. As there is some probability that atmospheric absorption is a physical cause of the changes of position observed in the zodiacal light, it may be well to begin by making the proposed system of corrections depend upon the difference of absorption, and afterwards to form another system, dependent upon the inclination of the ecliptic. After some allowance for the effect of absorption has been made by estimation, Table II. seems to indicate the existence of additional changes in the latitude of the axis, dependent upon the longitude. In attempting to obtain numerical corrections for the effect of absorption, we must accordingly compare the results furnished by groups of observations at longitudes not too widely separated. At the same time it does not seem advisable to con-

fine the comparisons to the few adjacent groups which differ only a little in longitude, since the unsystematic variations are evidently large. The remainders in absorption and latitude, given in Table II., were therefore adopted as the basis of the corrections.

The first step taken was to change the signs of corresponding remainders when necessary, so that those derived from the differences of absorption might all be positive. Among the nineteen remainders in latitude formed from the evening observations only four were then negative, and the corresponding remainders in absorption were small. Four negative quantities also occurred among the fifteen remainders in latitude formed from the morning observations. One of them corresponds to a large remainder in absorption; this is due to the influence of an abnormal group of observations, which will again be mentioned. The general agreement of the signs illustrates the dependence of the latitude upon the effects of absorption; but the variations in the relative magnitude of the remainders are too irregular to allow a satisfactory system of corrections to be immediately apparent from a graphical arrangement of the data. In order to avoid the possible effects of prejudice, without adopting a process involving more labor than would be warranted by the degree of accuracy to be expected in the result, the remainders derived from the differences of absorption were next arranged, according to their magnitude, in groups of five each, so far as practicable, and the corresponding remainders in latitude were also collected. In this manner four groups were formed from the evening observations, and three from the morning observations. In each part of Table III. the successive columns give the number of remainders in each group, their sums, their mean values, and their average deviations from these means.

TABLE III.

Evening Observations.							Morning Observations.						
No. Rem.	Sums.		Means.		Av. Dev.		No. Rem.	Sums.		Means.		Av. Dev.	
	Abs.	Lat.	Abs.	Lat.	Abs.	Lat.		Abs.	Lat.	Abs.	Lat.	Abs.	Lat.
5	0.07	$0^\circ.0$	0.01	$0^\circ.0$	0.01	$0^\circ.8$	5	0.22	$1^\circ.2$	0.04	$0^\circ.2$	0.02	$1^\circ.2$
5	0.31	4.8	0.06	1.0	0.01	0.7	—	—	—	—	—	—	—
5	0.93	8.6	0.19	1.7	0.06	0.8	5	0.73	7.2	0.15	1.4	0.06	0.5
4	2.17	14.0	0.54	3.5	0.15	1.0	5	1.85	19.6	0.37	3.9	0.10	6.2

The first and second groups of remainders from the morning observations agree so nearly with the first and third of those obtained from the evening observations that there seems to be no reason, so far as these groups are concerned, for adopting different systems of corrections in the two cases. The third group of morning observations approximately agrees with the fourth group of evening observations in the mean result for latitude, but not in that for absorption. This might suggest the use of different systems of corrections for the two series of observations, if the large average deviation in latitude, 6°.2, from the group under consideration did not show that very little relative weight can be attributed to the corresponding mean; for the average deviation in absorption, belonging to the same group, is not remarkably large. The relative weights of the means in latitude for the final groups of evening and morning observations, if computed by the ordinary rule,[1] would be 26 and 1. Under these circumstances, the discordant mean can hardly be used independently. Out of the five remainders from which it is derived, four are affected by two peculiar groups of observations in Table II. Each of these groups consists of seven observations, made about the same time. The limiting numbers of the charts for the first group are 110, 116, and for the second 130, 137. An examination of these charts, in the original work of Jones, will show that his observed positions of the eastern zodiacal light on the corresponding dates were really exceptional, and indicate the action of special causes, which cannot be traced at present. In the method of reduction here employed, the second of these abnormal groups of observations accidentally counteracts to some extent the effect of the other; for this reason the result may perhaps be allowed a small weight, instead of being rejected, as it would practically be with a weight of $\frac{1}{26}$. The course adopted was to combine the fourth group of evening and the third of morning observations with the relative weights 40 and 5; to combine with equal weights the first groups of evening and morning observations, as well as the third group of evening and the second of morning observations; and to employ the second group of evening observations independently. The four sets of mean remainders thus obtained are as follows: —

Variation in absorption.	Corresponding variation in latitude.
0.029	0°.12
0.062	0 .96
0.166	1 .58
0.523	3 .55

[1] Chauvenet, Spherical and Practical Astronomy, II. 494, 505.

If these results are laid down as points determined by rectangular co-ordinates, the abscissas representing the variations of absorption, expressed in tenths of a magnitude, and the ordinates representing variations in latitude, expressed upon the same scale in degrees, a curve passing through the origin and nearly through the projected points may be drawn with some confidence; but beyond the extreme point its course would be doubtful. Hence it seemed best to employ a curve of some simple theoretical form suggested by the graphical result. The curve selected was a parabola passing through the origin, with its axis parallel to the axis of abscissas. Upon this assumption, the mean values just obtained for the corresponding variations in absorption and in latitude will furnish four equations of condition, of the form $px + by = \frac{1}{2}y^2$, if we denote by $2p$ the parameter of the parabola, and by $-b$ the ordinate of the vertex. The solution of these equations by the method of least squares results in the values $2p = 4.77$ and $b = 1.70$. Hence the abscissa of the vertex is -0.61, and the equation of the parabola is $(y + 1.70)^2 = 4.77\,(x + 0.61)$, from which values of y in degrees may be obtained for values of x given in tenths of a magnitude. This parabola was charted, and the corrected latitudes, entered in the two columns of Table II. next to the last, were mostly found from the chart.

Results previously reached by other methods for the relation between absorption and latitude did not materially differ from those just given. The method here adopted has the advantage of leaving comparatively little to be arbitrarily determined.

The experiment was afterwards made of grouping the remainders derived from the inclination of the ecliptic and from the latitude of the axis in Table IV., the form of which resembles that of Table III.

TABLE IV.

Evening Observations.							Morning Observations.						
No. Rem.	Sums.		Means.		Av. Dev.		No. Rem.	Sums.		Means.		Av. Dev.	
	Incl.	Lat.	Incl.	Lat.	Incl.	Lat.		Incl.	Lat.	Incl.	Lat.	Incl.	Lat.
	°	°	°	°	°	°		°	°	°	°	°	°
5	7.5	0.4	1.50	0.08	1.5	0.6	5	16.1	11.0	3.22	2.20	2.2	2.4
5	47.3	1.3	9.46	0.26	2.0	0.9	5	58.0	2.5	11.60	0.50	2.6	1.3
5	86.4	8.7	17.28	1.74	2.3	0.6	—	—	—	—	—	—	—
4	212.2	15.6	53.05	3.90	5.1	0.4	5	191.9	29.9	38.33	5.98	11.1	3.7

Other groupings were also tried. In all cases the evening observations seem to be sufficiently accordant, but the morning observations so much more irregular than when they were grouped according to variations of absorption that they cannot be advantageously combined with the evening observations. An attempt to do this gave corrections for the evening observations, which themselves unmistakably required systematic correction for the inclination of the ecliptic. For the evening observations separately a uniform system of corrections, represented graphically by a straight line from the origin through the point corresponding to the fourth group in Table IV., appeared to be as satisfactory as any. The corrected latitudes given for the evening observations in the last column of Table II. were thus obtained. For the morning observations, the quantities in the same column were obtained from a system of corrections represented by a straight line from the origin through the point corresponding to the mean of the final groups of evening and morning observations in Table IV. The choice of this point is arbitrary, and the result, accordingly, uncertain.

The three columns of corrected latitudes in Table II. exhibit systematic variations dependent upon the longitude, and both the evening and the morning observations agree in placing the axis of the light in north latitude for about fifty degrees on each side of the autumnal equinox. Near the vernal equinox the results are more irregular, with a tendency to south latitude. Our present knowledge does not warrant the assumption that the axis should lie on any great circle; on the other hand, we should not be entitled to regard the results of the evening observations as showing that the axis crosses the ecliptic more than twice. But after making any reasonable allowance for error in the observations and in the method of reduction, it can hardly be doubtful that the axis of the "Stronger Light," as seen by Jones at the elongation 60°, was decidedly north of the ecliptic near the autumnal equinox, and considerably farther south, if not actually in south latitude, near the vernal equinox. It will appear on examination that only an obviously excessive correction for absorption or for the position of the ecliptic will remove the evidence of this variation in the evening observations, while it happens in the case of the morning observations that those made near the autumnal equinox cannot be subject to large corrections on any system.

It will now be interesting to compare this result with one obtained from observations of the faint light, called "Gegenschein," and occasionally seen in approximate opposition to the Sun. Its centre is usually somewhat to the north of the ecliptic, which may indicate an effect of atmospheric absorption; but this question

cannot well be determined without the aid of observers stationed in the southern hemisphere, while hitherto the light has been seen only at northern stations. From some observations collected upon a former occasion, however, it appears that, near the vernal equinox, the observed position of the light is occasionally south of the ecliptic, while between the longitudes 140° and 220° it often attains a greater north latitude than elsewhere. It was the conclusion thus reached that led to the present inquiry with regard to the position of the zodiacal light according to the observations of Jones. The agreement of the two results may make it worth while to repeat in a condensed form a list of mean positions for "Gegenschein" given in the article just mentioned.[1] The headings λ and β indicate approximate longitudes and latitudes. The mean result for each column is given at its foot.

λ	β	λ	β	λ	β	λ	β	λ	β	λ	β
°	°	°	°	°	°	°	°	°	°	°	°
137	+2	160	+2	188	+3	213	+3	341	0	10	−3
150	+3	165	+1	189	0	220	0	342	+2	13	−2
150	+5	170	0	192	+2	220	0	345	+2	18	−1
152	+6	170	+1	199	0	223	0	351	−2	34	+2
154	+3	176	0	204	+1	229	−2	356	0	..	..
157	+4	181	0	208	0	...	..	3	−1	..	..
150	+4	170	+1	197	+1	221	0	350	0	19	−1

If any corrections for absorption could be applied to these latitudes, they would presumably all be negative, and numerically smaller in the first, second, and sixth columns than in the others, since the observations were all made near the meridian. Hence the difference between the first column and the rest would rather be increased than diminished by the corrections. There is accordingly no similarity in detail between these results and those of Table II., while their general resemblance is obvious. It will afford an additional reason for regarding the latitude of the zodiacal light as actually variable in accordance with its longitude. The strength of this reason will depend upon the degree of confidence which may be felt in the actual appearance of part of the zodiacal light in the form of "Gegenschein."

Although this faint light in opposition to the Sun has been seen by very few observers, some of them have expressed great confidence in its existence, and it has been three times independently discovered, — by Brorsen,[2] Backhouse,[3] and

[1] Astronomische Nachrichten, CIX. 259.
[2] Astronomische Nachrichten, XLII. 219.
[3] Monthly Notices of the Royal Astronomical Society, XXXVI. 46.

Barnard.[1] It so happens that those who see the phenomenon best have been prevented by other occupations from observing it frequently and with precision, or at least from publishing in detail, and in some generally accessible place, the observations which they may have made. But in view of the triple discovery of "Gegenschein," and of the considerable, though fragmentary, mass of published observations respecting it, little doubt can be felt of its reality. Assuming it to exist, the probability that it is part of the zodiacal light is certainly strong, although there is no easy theoretical explanation of its appearance. The readiest way of accounting for it, on the meteoric theory of the zodiacal light, would be to assume such a law for the phases of the meteors that their brightness would rapidly increase as they approached opposition. Some indications of the possibility of such an increase have been given in a former communication.[2] A less natural explanation might be sought in the possible perturbations of meteoric matter by the Earth.[3]

The conclusion that the zodiacal light lies farther to the north near the autumnal than near the vernal equinox may accordingly be regarded as considerably strengthened by the agreement between the observations of "Gegenschein" and those made by Jones of the brighter portions of the zodiacal light. In any future observations of either kind, it will be interesting to notice whether further evidence in support of this conclusion is obtained. Perhaps it will also be possible to define the position of the light more accurately than could be done by the older methods of observation, and to trace any progressive changes which may occur in it.

The main hindrance to the development of the meteoric theory of the zodiacal light is the want of trustworthy information with regard to the probable phases of the meteors. Writers who have attempted to treat the subject mathematically[4] have hitherto contented themselves with Lambert's formula, $\sin v - v \cos v$, which has a very imperfect foundation in experiment, and does not apply to the phases of rough bodies, even if the hypotheses on which it rests are correct. Experiments are now in progress, however, at the observatories of Munich[5] and of Harvard College, which may add considerably to our knowledge of the laws of irregular reflection. After enough information of this kind has been collected,

[1] Sidereal Messenger for November, 1883, II. 254.

[2] Proceedings Am. Acad., XIX. 310.

[3] Astronomische Nachrichten, CII. 266.

[4] Schiaparelli, Entwurf einer astronomischen Theorie der Sternschnuppen (German translation by Boguslawski), p. 194; Geelmuyden, Remarques sur la théorie de la lumière zodiacale, p. 104.

[5] Vierteljahrsschrift der Astronomischen Gesellschaft, XX. 111.

it will become more practicable to compute the theoretical amounts of light at various elongations which would result from any given hypothesis with regard to the distribution of meteors in the Solar System.

In any such computation, it will probably be found that between the vertex of the ordinary zodiacal light and the region at the elongation 180° the light will remain nearly constant for a considerable arc of longitude. This, at least, was the result of some unpublished computations, made a few years ago upon various hypotheses of the distribution of the meteors and the effect of their phases. The existence of the zodiacal band, reported by Brorsen, Schmidt, and other observers, would be wholly consistent with this conclusion; but it is still a little uncertain whether the observed zodiacal bands may not be due to faint streams of stars. It rather singularly happens that on both sides of the Milky Way the existence of such streams is indicated by the Durchmusterung. The narrow band from the Pleiades has been fully discussed elsewhere,[1] and on recent examination it appeared that a similar stream of Durchmusterung stars extends along the ecliptic from ϵ *Cancri* to β *Virginis*. The region examined was that portion of the Durchmusterung from $8^h\ 0^m$ to $13^h\ 0^m$ in right ascension, and from $-2°$ to $+28°$ in declination. Within this region, the number of stars in each 4^m of right ascension was counted for each degree of declination, and, north of $+12°$, these numbers were multiplied by the secants of the corresponding declinations. The numbers thus corrected represent observed stellar densities, the unit of area being the square degree, but the corrections are everywhere small. With the aid of Dien's Atlas, the epoch of which, 1860, is sufficiently near that of the Durchmusterung for the present purpose, a line was laid down through the region along the middle of the assumed course of a permanent band of faint light, which appears to me to be visible there.[2] Several other lines were drawn at distances of two and a half degrees apart, on either side of the principal line. For each hour of right ascension, the corrected number of Durchmusterung stars in each square degree intersected by the lines was taken from the list previously prepared, and the mean result was found for each line. These means, which are given in Table V., do not support the hypothesis that the observed band is due to an accumulation of stars, except in the first part of its course, where it is obliquely intersected by the ecliptic. The first column of Table V. gives a number for the designation of each line; the principal line is No. 5, and is drawn through ϵ *Cancri* to *o* *Leonis*, thence south of the ecliptic so as to pass about

[1] Astronomische Nachrichten, XCIX. 91, 369.

[2] Astronomische Nachrichten, CII. 265.

midway between σ and ϕ *Leonis*, and afterwards to *Coma Berenices*. The other columns are divided into groups of three for the successive hours of right ascension. In each group the first column gives the number of square degrees crossed by the line, the declination of the southern border of the first square, in Italics if negative, and the mean number of stars to the square degree. The vacant spaces show that the course of the lines sometimes carries them beyond the adopted limits of declination.

TABLE V.

No. of Line.	8^h.			9^h.			10^h.			11^h.			12^h.		
	No.	Decl.	Mean.	No.	Decl.	Mean.	No.	Decl.	Mean.	No.	Decl.	Mean.	No.	Decl.	Mean.
		°			°			°			°			°	
1	19	14	13.1	12	3	11.2	—	—	—	—	—	—	28	*2*	8.9
2	22	17	13.5	22	6	10.7	—	—	—	5	*2*	10.6	31	0	8.1
3	22	20	15.9	21	9	10.2	8	0	9.4	11	*2*	9.1	32	3	9.4
4	19	23	16.2	19	12	9.6	15	3	8.1	19	*1*	9.3	27	6	7.9
5	21	26	16.7	21	15	11.0	17	6	8.7	17	1	8.8	22	10	7.8
6	20	27	14.0	19	17	12.9	16	8	9.9	20	4	7.2	19	14	7.4
7	12	27	11.0	21	20	12.6	18	11	10.0	23	6	7.7	10	20	9.9
8	7	27	11.0	19	23	11.3	17	14	10.4	24	9	8.0	3	25	10.3
9	2	27	7.0	20	26	11.1	17	16	8.0	25	11	9.7	—	—	—
10	—	—	—	15	27	10.5	18	19	9.4	22	14	9.1	—	—	—
11	—	—	—	11	27	10.9	16	22	9.7	16	16	8.9	—	—	—
12	—	—	—	6	27	7.3	18	24	9.7	10	19	10.1	—	—	—

In 8^h, 9^h, and 10^h there is a slight maximum of stars, which appears later in the series of lines in each successive hour. If the position of the lines is examined, it will appear that the maximum approximately follows the course of the ecliptic. The lines run northward in 11^h and 12^h, so that for these hours no indication is given in Table V. of the relative frequency of stars near the ecliptic, and it only appears that the stars of the Durchmusterung are relatively few upon the course of the supposed band. If other observers should consider that any band of faint light occurs there, the possibility of a diffused nebulosity in this part of the sky (which abounds in telescopic nebulae), might be suggested.

Another faint band of light[1] appears to me to be situated south of β and η *Virginis*. This region is too near the southern limit of the Durchmusterung to allow the distribution of stars in it to be well studied from that catalogue. But so far as evidence can be obtained from it by the method above explained, it would seem that along the line passing approximately through β and η *Virginis*

[1] Astronomische Nachrichten, CIX. 262.

themselves, which nearly coincides with the ecliptic, the number of Durchmusterung stars to the square degree is slightly greater than on other lines parallel to it on each side. To complete the inquiry thus suggested, straight lines were laid down on the chart between the limits of right ascension $10^h\ 0^m$ and $12^h\ 0^m$, with the following limits in declination: $+6°$ to $-5°$; $+8°$ to $-3°$; $+10°$ to $-1°$; $+12°$ to $+1°$; $+14°$ to $+3°$; $+16°$ to $+5°$; $+18°$ to $+7°$. The first two of these lines extend beyond the limits of the Durchmusterung. The numbers of square degrees within these limits which are intersected by the lines are respectively 26, 32, 36, 36, 36, 36, 36; and the corresponding mean numbers of Durchmusterung stars to the square degree are 9.0, 9.7, 10.0, 9.9, 9.3, 8.5, 8.4. Here again a slight maximum is indicated for the vicinity of the ecliptic. It accordingly seems to be a fact, so far as it can be determined by the Durchmusterung, that there is a slight relative abundance of stars all along the ecliptic between the limits of right ascension $8^h\ 0^m$ and $13^h\ 0^m$. This conclusion is confirmed by inspection of the Durchmusterung atlas. It is not at present to be assumed that the distribution of the fainter stars follows the same rule, or that the slight variations of stellar density here found are sufficient to be distinguishable to the eye of an observer; still, considering the faintness of the zodiacal bands occasionally reported, their nature may perhaps be rendered a little doubtful by the statistics of the distribution of Durchmusterung stars which have just been considered. In time to come, photography may resolve some of the difficulties now attending inquiries of this kind.

The orbits of the known asteroids naturally suggest themselves as another possible source of information with regard to the distribution of light in the zodiac. The discovery of so many small planets between Mars and Jupiter makes it seem somewhat probable that large quantities of meteoric dust may circulate in the same region, and in orbits similar to those of the separately visible objects which have been found there. The appearance of this dust from a distance might have a general resemblance to that which would result if the asteroids left permanent traces of light behind them in their movements. But in attempting to determine this effect from the orbits of the asteroids hitherto discovered, it must be remembered that the circumstances under which the search for them has been conducted may produce apparent peculiarities in their distribution.

The elements of the first 237 asteroids, as given in the Berlin Jahrbuch for 1887, have accordingly been examined with some care, and several tabular arrangements of these elements have been formed, to exhibit any peculiarities which

they might present. Upon the whole, it does not seem necessary that the details of these investigations should here be given at length, since it is not certain that the classification employed would be serviceable to other inquirers, and since the rapid discovery of new planets would soon deprive the results thus exhibited of any appearance of completeness. It will perhaps be interesting, however, to state the general conclusions which were obtained from the tables.

Upon the comparison of elements published twenty or thirty years ago with others computed for recent epochs, it appears that the orbits of asteroids do not generally vary with such rapidity as to invalidate, in the course of half a century at least, any statistical results like those here described. The distribution in longitude of the ascending nodes of the known asteroids was the first subject of inquiry, and the conclusion was obtained that the zodiacal band formed by the collective orbits would have its least extension in north latitude about the longitude 0°, and its least extension in south latitude about the longitude 180°. The coincidence of this result with that already found for the zodiacal light induced me to try the effect of a stereographic projection of the northern halves of the orbits on the plane of the ecliptic. In this projection, the nodes and inclinations of the orbits were the only elements employed, so that the supposed band was regarded as seen from the Sun. The radius of the projection was five inches. Upon this scale a distinct band of shading was formed by the lines representing the orbits of the first 120 asteroids; the remaining 117 were laid down upon a separate chart. Both charts, but especially the first, exhibited a depression of the edge of the band in the region near the longitude 0°, as had been expected. The same charts will also represent the southern halves of the orbits if we regard all the longitudes as increased by 180°.

Farther examination showed that the asteroids to which this peculiarity is due are those having their perihelia in south latitude. The general result thus obtained may be sufficiently well exhibited by stating the number of ascending nodes for each quadrant of longitude, beginning at 40°, which occur in the orbits of asteroids having their perihelia respectively in north and in south latitude.

Longitudes of ascending nodes.	40° to 130°.	130° to 220°.	220° to 310°.	310° to 40°.
Perihelia in north latitude . . .	23	40	23	45
Perihelia in south latitude . . .	32	38	6	30
Total	55	78	29	75

The band formed by the collective orbits with perihelia in north latitude, accordingly, would not have any distinct tendency towards north and south latitude

in different quadrants, although its width might vary. The two maxima and minima may probably be explained by the consideration that discoveries of asteroids are usually made near opposition, and are more likely to be made near a node than elsewhere. Such discoveries, with unimportant exceptions, have hitherto been made in Europe or in the United States, where the weather and the position of the ecliptic in the visible hemisphere make the winter and summer months less favorable than the spring and autumn to the search for new planets. In Chambers's Astronomy, edition of 1877, the dates of discovery of the first 169 asteroids are given: 51 occur in March, April, and May; 35 in June, July, and August; 62 in September, October, and November; and 21 in December, January, and February. Hence the asteroids most likely to be discovered have hitherto been those having nodes in the parts of the ecliptic which come into opposition in autumn and spring.

But since a planet may apparently be discovered as readily near one of its nodes as near the other, the peculiar distribution of the nodes of the orbits with southern perihelia cannot easily be explained by the circumstances under which the discoveries have been made. There is, however, no very strong reason to think that it indicates any systematic peculiarity in the orbits of asteroids in general; for we see that the reversal of the nodes of only thirteen orbits would be enough to eliminate it from the statement just given of the number of ascending nodes in different quadrants. Still, this number, thirteen, is about one eighteenth of the total number of orbits under discussion, so that it is not relatively insignificant, although it is evident that the discovery of a much larger number of small planets than are now known will be desirable for determining the question whether there is any marked irregularity in the distribution of the nodes of such objects in general.

If we assume that the distribution of the nodes, in the case of meteoric particles at about the distance of asteroids, is correctly indicated by the asteroids already known, it follows that the zodiacal band formed by their collective orbits would show a tendency to north latitude at the longitude 180°, and to south latitude at 0°; for the deficiency of ascending nodes in the quadrant from 220° to 310° would occasion a deficiency of extreme north latitudes in the quadrant from 310° to 40°, and a similar deficiency of extreme south latitudes in the quadrant from 130° to 220°. Moreover, the tendency to north latitude at 180° would be stronger than that to south latitude at 0° if the entire effect were due to particles having perihelia in south latitude; for, in that case, the deficiency in south lati-

tudes in the quadrant from 130° to 220° would be enhanced by the deficiency of perihelia, even when viewed from the Sun. To a terrestrial observer, the effect would be still farther increased by the result of parallax, when the region observed was in opposition. The coincidence of this theoretical result with that derived from the observations of "Gegenschein" is not for the present to be regarded as anything more than a suggestion, which may lend additional interest to future observations of light in the zodiac, and also to the discovery of more small planets, which is often regarded as leading to no result of consequence.

The six asteroids having southern perihelia, and ascending nodes between the longitudes 220° and 310°, are Hygiea (10), Pomona (32), Aethra (132), Polana (142), Xanthippe (156), and Loreley (165). The orbit of Aethra has a large inclination and eccentricity; those of the five others are not distinguished by any peculiarity except that of the position of their nodes. The approximate longitudes of the ascending nodes of these planets are respectively 286°, 221°, 260°, 292°, 246°, and 304°; the corresponding values of the angles in the planes of their orbits by the amounts of which their perihelia follow their ascending nodes are 311°, 333°, 253°, 289°, 270°, and 333°.

Upon the hypothesis that a noticeable amount of light is reflected to us by meteors not more than two or three times farther from the Sun than we are, this light would vary its position in longitude according to its elongation. At its eastern elongation it would precede its heliocentric longitude, which it would follow at its western elongation. Applying these considerations to the case of the evening and morning zodiacal light, we see that if the light would tend to south latitude at the longitude 0° as seen from the Sun, then, as seen from the Earth, and at the elongation 60°, the evening zodiacal light should be farthest to the south at the longitude 340° or still sooner, while the morning light should have its greatest southern latitude at 20° or later. A similar effect of parallax might be expected at the maximum of north latitude. A reference to Table II. will show that indications of these effects are in fact presented by the observations of Jones. The coincidence is worth attention, although the uncertainty of the correction for atmospheric absorption employed in Table II. makes it difficult to obtain more than a general conclusion from the corrected latitudes.

It has been shown that the symmetrical part of the variation noticed above in the number of ascending nodes at different longitudes may perhaps be due to the circumstances under which asteroids have been discovered. But if we suppose it to indicate a general tendency of such bodies, the band which they would form

should be narrower near the longitudes 0° and 180° than near the longitudes 90° and 270°. The column in Table II. giving half the extent of the zodiacal light in latitude was inserted in order to exhibit any striking variations in the dimensions of the light at different longitudes. The variations which appear in it, however, are not large enough to allow any safe inference from them, unless we could correct them like the latitudes, which seems to be impracticable. They have some relation to the changes in the difference of absorption at the boundaries, but this would naturally result from the manner in which the difference of absorption was determined. When the light was observed to be wide, the computed difference of absorption is of course larger than when the observed light, under similar circumstances, was relatively narrow. On comparing the observed width with the corresponding results for the inclination of the ecliptic to the horizon, no systematic variation was detected. It seems probable that the width of the light, as observed by Jones, was subject to considerable variation on account of the meteorological conditions prevailing at the time of observation. As the observations were made in various climates and at all seasons of the year, there is little reason to expect from them the discovery of any systematic variation in the width of the light, dependent either upon its zenith distance or upon its longitude.

Besides the longitudes of the ascending nodes, the other elements determining the form and position of the orbits of asteroids were discussed, but without many results here requiring notice. The inclinations do not appear to depend upon the longitudes of the nodes, the relative proportions of small and large inclinations not showing any marked changes at different longitudes. In all, the number of inclinations less than 5° is 78; between 5° and 10°, 86; between 10° and 15°, 45; greater than 15°, 28. We may probably infer that the band formed by the collective orbits would approach the latitude of 10°, north and south, with little diminution of brightness, and would afterwards become fainter rather rapidly. But it should be remembered that asteroids with large inclinations are less likely than others to be discovered.

The longitudes of the perihelia, using that term in the customary sense, show a tendency to accumulate near the vernal equinox. Between 300° and 60° there are 122 perihelia, while in the remaining 240° of longitude there are only 115. It is not easy to explain this peculiarity by the circumstances under which asteroids have been found. If it indicates a real inequality, the band formed by the collective orbits should on the whole be relatively bright, and, in opposition, rela-

tively wide, near the longitude 0°. The zodiacal light usually attracts most attention by its brilliancy near that longitude; but we need careful photometric observations in both hemispheres to determine whether this apparent brilliancy is not wholly due to the favorable position of the zodiac in the sky of the northern hemisphere during the evenings at the end of winter.

No remarkable relation between the longitudes and latitudes of the perihelia was noticed. The accumulation just mentioned occurs both in north and in south latitude. The mean distances and eccentricities, also, are not apparently connected by any relation with the longitudes of the perihelia. There is a slight preponderance of large eccentricities with perihelia in north latitude between the longitudes 300° and 360°, and a similar preponderance of large eccentricities with perihelia in south latitude between the longitudes 0° and 60°.

The number of perihelia in north latitude is 131, in south latitude 106. As asteroids will be most readily discovered near their perihelia, and at a considerable altitude, the excess of perihelia in north latitude may be due to the northern stations of the discoverers. This consideration, however, fails to account for the remarkable distribution of the ascending nodes of asteroids with southern perihelia which has already been discussed.

The principal fact noticed with regard to the mean distances was that the more recently discovered asteroids have on the whole larger mean distances than the others, as might naturally be supposed. Taking the distance for which $\log a = 0.437$ as the limit between small and large distances, we find among the first 120 asteroids 71 relatively near, and 49 remote; the corresponding numbers for the next 117 are 51 and 66. It is also noticeable that the remoter asteroids have less eccentric orbits than the rest. If the value of the eccentricity for which $\phi = 9°$ is taken as the limit, there are 57 of the nearer asteroids with orbits of small eccentricity, and 65 with decidedly eccentric orbits; for the remoter asteroids the corresponding numbers are 67 and 48. But these peculiarities have no apparent connection with the present subject.

It may be shown mathematically that if the zodiacal light is due to meteoric dust diffused through the Solar System, those particles far beyond the orbit of Jupiter can add little to its brightness, upon any reasonable hypothesis with regard to the distribution of the meteors. But at mean distances of 2 or 3, the effect would not be relatively insignificant, and the existence of the asteroids, as has been said, suggests the possibility that very minute planets may accompany them in large numbers. It scarcely needs to be said that meteoric dust in the

region of the asteroids cannot account for all the phenomena of the zodiacal light; we must in any case suppose that a great part of the light comes from particles much nearer to the Sun.

The various resemblances between different groups of phenomena which have been pointed out in the preceding pages may be entirely fortuitous, and should not be regarded as a satisfactory basis for any theory of the zodiacal light. But it is only by taking notice of such resemblances when they occur that we can be guided in subsequent observations. This consideration appears to me sufficiently important to justify the foregoing discussion. Perhaps the results above described might be either invalidated, or decidedly confirmed, by additional examination of the published work of observers of the zodiacal light, and especially of the material provided by the energy of Jones. But the labor to be undertaken in the necessary reductions is considerable, and the corrections to be applied must remain uncertain. Accurate knowledge of the phenomena of the zodiacal light can be expected only from photometric observation. To whatever extent these difficulties may hinder the derivation of additional knowledge from the work of Jones, his memory will always be honored for the unusual assiduity which he displayed in observations of the zodiacal light, and for his discovery of the first law tending to explain its apparently irregular phenomena.

Cassini's opinion, that the axis of the zodiacal light lies in the plane of the Sun's equator, was partly founded upon observation. But the observations by Cassini, quoted by Jones at the end of his work, are insufficient to establish any such conclusion. It seems from them, however, that Cassini saw the light generally farther to the north in Leo and Virgo than in Pisces and Aries, even after making some allowance for the effect of absorption. This effect, on the other hand, would sufficiently explain the northward tendency of the light during the month of April, which suggested to Cassini the hypothesis above mentioned. On merely theoretical grounds it has some claim to consideration; for it is possible that the rotation of the Sun indicates the fundamental plane of the Solar System, if we accept the ordinary nebular hypothesis of its formation, more correctly than can be done by the revolutions of the known planets. Since the longitude of the ascending node of the Sun's equator is about 75°, the results of the present inquiry agree tolerably well with Cassini's hypothesis.

The reduction of fifty-eight observations, by various observers, of the vertex of the zodiacal light, made by Houzeau in 1844,[1] gave for the longitude of its

[1] Astronomische Nachrichten, XXI. 186.

ascending node 2°, with the inclination 4°. In the present state of our knowledge upon the subject, this result cannot be regarded as significant, since the material employed was necessarily insufficient.

The principal conclusions reached in the present communication may now be recapitulated as briefly as possible: —

1. It is probable that atmospheric absorption largely affects the apparent position of the zodiacal light.

2. After allowance for the effect of absorption, there is reason to think that the zodiacal light, as seen during the second half of the nineteenth century, has had a more northern latitude near the longitude 180° than near the longitude 0°.

3. Upon the meteoric theory of the zodiacal light, it is to be expected that a continuous zodiacal band should be present; but the question of its actual visibility is complicated by the slight maxima of stellar density which are situated along those parts of the ecliptic most readily accessible to observation from stations in the northern hemisphere.

4. The belt of sky occupied by the projections of the orbits of the first 237 asteroids presents certain peculiarities which correspond to those of the zodiacal light, and suggest the hypothesis that the light may be partly due to minute objects circulating in orbits like those of the smaller planets.